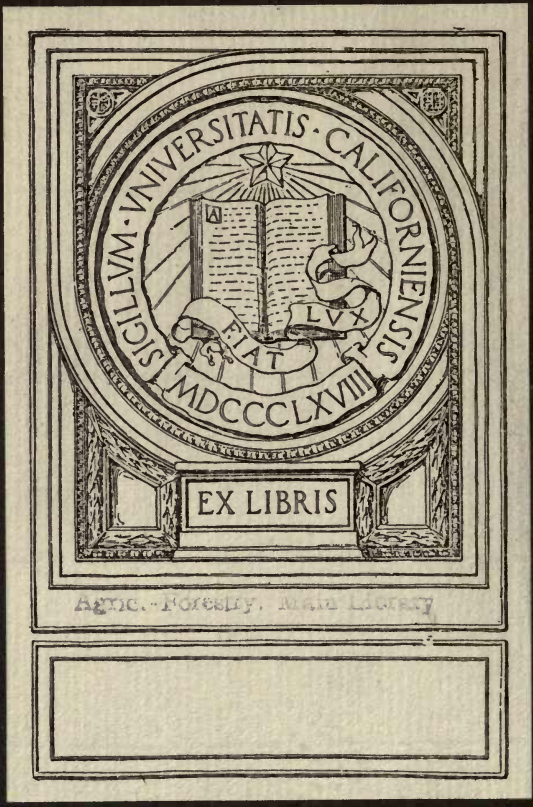
GROWTH OF OAK IN THE OZARKS
Univ. of Missouri College of Agri.
Agri. Experiment Station
Research Bulletin 41
March, 1921


SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
MDCCCLXVIII
LVX
FIAT
EX LIBRIS

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 41

GROWTH OF OAK IN THE OZARKS

COLUMBIA, MISSOURI
MARCH, 1921

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 41

GROWTH OF OAK IN THE OZARKS

(Publication Authorized October 20, 1920)

by

Frederick Dunlap

COLUMBIA, MISSOURI
MARCH, 1921

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

STATION STAFF

MARCH, 1921

AGRICULTURAL CHEMISTRY

C. R. Moulton, Ph. D.
L. D. Haigh, Ph. D.
W. S. Ritchie, A. M.
E. E. Vanatta, M. S.[2]
R. M. Smith A. M.
T. E. Friedmann, B. S.
A. R. Hall, B. S. in Agr.
E. G. Sievekıng, B. S. in Agr.
G. W. York, B. S. in Agr.
C. F. Ahmann, A. B.

AGRICULTURAL ENGINEERING

J. C. Wooley, B .S.
Mack M. Jones, B. S.

ANIMAL HUSBANDRY

E. A. Trowbridge, B. S. in Agr.
L. A. Weaver, B. S. in Agr.
A. G. Hogan, Ph. D.
F. B. Mumford, M. S.
D. W. Chittenden, B. S. in Agr.
Paul B. Barnard, B. S. in Agr.
A. T. Edinger, B. S. in Agr.
H. D. Fox, B. S. in Agr.

BOTANY

W. J. Robbins, Ph. D.
E. F. Hopkins, Ph. D.

DAIRY HUSBANDRY

A. C. Ragsdale, B. S. in Agr.
W. W. Swett, A. M.
Wm. H. E. Reid, A. M.
Samuel Brody, M. A.
C. W. Turner, B. S. in Agr.
D. H. Nelson, B. S. in Agr.

ENTOMOLOGY

Leonard Haseman, Ph. D.
K. C. Sullivan, A. M.
O. C. McBride,

FIELD CROPS

W. C. Etheridge, Ph. D.
C. A. Helm, A. M.
L. J. Stadler, A. M.
O. W. Letson, B. S. in Agr.
E. O. Pollock, B. S. in Agr.
B. B. Branstetter, B. S. in Agr.

RURAL LIFE

O. R. Johnson, A. M.
S. D. Gromer, A. M.
R. C. Hall, A. M.
Ben H. Frame, B. S. in Agr.

FORESTRY

Frederick Dunlap, F. E.

HORTICULTURE

V. R. Gardner, M. S. A.
H. D. Hooker, Jr., Ph. D.
J. T. Rosa, Jr., M. S.
F. C. Bradford, M. S.
H. G. Swartwout, B. S. in Agr.

POULTRY HUSBANDRY

H. L. Kempster, B. S.

SOILS

M. F. Miller, M. S. A.
H. H. Krusekopf, A. M.
W. A. Albrecht, Ph. D.
F. L. Duley, A. M.
R. R. Hudelson, A. M.
Wm. DeYoung, B. S. in Agr.
H. V. Jordan, B. S. in Agr.
Richard Bradfield, A. B.
O. B. Price, B. S. in Agr.

VETERINARY SCIENCE

J. W. Connaway, D. V. S., M. D.
L. S. Backus, D. V. M.
O. S. Crisler, D. V. M.
A. J. Durant, A. M.
H. G. Newman, A. M.

ZOOLOGY

George Lefevre, Ph. D.

OTHER OFFICERS

R. B. Price, M. S., Treasurer
Leslie Cowan, B. S., Sercretary
S. B. Shirkey, A. M., Asst. to Director
A. A. Jeffrey, A. B., Agricultural Editor
J. F. Barham, Photographer
Miss Bertha Hite,[1] Seed Testing Laboratory.

[1]In service of U. S. Department of Agriculture.
[2]On leave of absence

GROWTH OF OAK IN THE OZARKS

FREDERICK DUNLAP

INTRODUCTION

The objects of this publication are to show the rate of growth of the principal species of oak on certain poor soils of the Ozark Region of Missouri; to furnish volume tables for use in computing the volumes of standing timber; and to furnish a preliminary basis for the selection of those species of timber trees best fitted for cultivation under forestry practice in this region.

Timber trees are selected on the basis of the growth they make. To learn the productivity of any annual crop like corn, it is sufficient to measure the harvest. In an orchard such simple procedure is no longer sufficient. Measuring the productivity of a forest is a still more complicated procedure because there is, as in the orchard, a juvenile period during which no crop can be harvested and the forest lacks what the orchard has, a definite ripening of the crop when it must be gathered or lost. The decision as to when a forest crop is ripe rests on financial rather than biological consideration. A given oak forest may be managed for the production of either mine props, railroad ties, saw timber or veneer logs; and which is the most profitable product depends on market price in relation to growing period. Forest productivity varies from decade to decade in the same stand and its measurement is not a simple matter.

This bulletin deals with one factor of forest productivity—the growth of the individual tree. Other factors are density of stand, soil and climate. Soil and climate are usually considered together and termed "site." This bulletin sets forth the results of measurements and comparisons of the rate of growth of the four most important oaks of the Ozark Region of Missouri when grown under identical conditions of stand and site. The species studied are black oak, black jack oak, white oak and post oak and the environment is that which has existed in this particular locality during the past two centuries. The growth is shown in detail in Tables I to VIII and is shown graphically in the plates.

Black oak and white oak attain a volume of one cord when 19 inches in diameter; half a cord at 14 inches and a quarter of a cord at 11 inches. As between the two, black oak grows much

more rapidly than white oak during the first century. The ratio of their growths depends on the age at which comparison is made. At 100 years the white oak is 10 inches in diameter, 52 feet high and has a volume of 13 cubic feet, while the black oak is 15 inches in diameter and 66 feet high with a volume of 37 cubic feet. A comparison of the growth of black oak and white oak with the same or related species in the mixed hardwood forests of Kentucky and Tennessee indicates that white oak grows more slowly and black oak more rapidly in Missouri.

The growth of post oak and black jack oak is slower—too slow to warrant favoring either of them in the future forests of the Ozarks. Black jack has neither silvicultural value nor wood quality to recommend it while the desirable features of the post oak appear to be adequately filled by the white oak. The data collected for this report does not warrant a comparative study of the black oak, red oak, Texan oak, and Spanish oak and these are grouped as one species. It remains for later investigations to furnish material for this comparison.

There are approximately seven million acres of land in the Ozark Region of Missouri that are better adapted to the growth of timber than to the growth of any other crop. Among the different kinds of soil, that known as Clarksville stony loam covers large areas and is found in all parts of the Ozark Region. It naturally varies considerably and while there are many acres of this type that may be cultivated, at least a corresponding area of other types cannot be farmed with profit. Wherever the ground is too rough or too rocky or too poor for cultivation it would better be kept in timber. Trees will grow there and cattle can graze on the forage produced in the forest as it approaches maturity.

FOREST SOIL—THE CLARKSVILLE STONY LOAM

Appearance and Composition.—The typical forest soil of the Ozark Region of Missouri is Clarksville stony loam. "In its general characteristics Clarksville stony loam is a gray, very stony silt loam with a gray or pale yellowish stony, silty clay subsoil. The fine material of the lower subsoil is usually reddish brown in color and a clay in texture.....From 25 to 90 percent of the soil mass consists of chert fragments ranging in size from small particles to pieces several feet in diameter. Sometimes the surface is so thickly strewn with these fragments as to form almost a complete covering. In the subsoil of the very stony areas the chert

is commonly fitted together somewhat in the form of the original rock, but in most places the lower stratum consists of a compact mass of cherty gravel and reddish clay. Rock outcrops and stony cliffs are numerous. In general, the south and west slopes always contain more stones than the north slopes, a condition found in all the gravelly and stony soils of the Ozark Region.....

Origin.—"The rocks giving rise to the Clarksville stony loam consists mainly of very cherty limestones, with occasional thin beds of sandstone. The resulting soil therefore is very stony and such fine material as is formed is largely washed away."*

Topography and soil phases.—Clarksville stony loam occupies a large per cent of the roughest part of the Ozark Region. The surface is mainly a succession of narrow ridges, alternating with deep ravines. Relative elevations are seldom in excess of 200 feet. On some of the broader ridges and northern slopes this soil type gives way to a gravelly loam, the chief distinguishing characteristic being a lower per cent of rock content. At the foot of the longer slopes, along fair sized streams, the finer soil particles from the hills accumulate and form what is known locally as bottom land.

Agriculture and Grazing. Most of the farms have been located on the better grades of soil. They are found in the bottoms or on the flat ridge tops and extend along the north slopes—places where the rock content is lowest. Much of the area occupied by soils of the Clarksville type is too rocky, rough and dry to raise field crops. During favorable seasons yields of 25 bushels of corn, 15 bushels of wheat or a ton of hay an acre are attained. Very often, however, the crops are almost complete failures.

Stock raising has from the earliest settlement of this region contributed largely to the farmers' income. Many localities still contain large areas of wild land usually owned by non-residents and entirely unfenced. Such tracts constitute a free range the area of which is largely increased by the unfenced portion of farms. "Most of the range is very poor, especially for cattle.....In a few remote sections of the southern counties cattle still do well on the range. The nature of the range in most parts, however, is such that the production of beef of good quality is out of the question."†

*M. F. Miller and H. H. Krusekopf, "Soils of Missouri," Bulletin 153, Mo. Agr. Exp. Sta. p. 81.

†Sauer, "The Geography of the Ozark Highland of Missouri," p. 185.

Because it calls for small initial investment the production of scrub cattle on open range is still generally practiced. Hog raising particularly of the bacon breed is better adapted to the nature of the country.

"For the raising of hogs conditions are much better, as the abundance of acorns and other mast makes the average range fairly good."*

THE FOREST

Composition.—Various species of oaks make up the bulk of the forest on the Clarksville stony loam, chief among them being black, red, Spanish, black jack, white and post oaks while there is also a scattering of hickory and some sour gum in places. The mixture is not uniform but there are stands of all graduations from an almost pure stand of any one of the principal species to an almost even mixture of all species except gum. In general, the broader ridge tops support a growth of post oaks while near the break of the slopes or on top, black jack in varying numbers is found. Most of the slopes bear a stand of either the black or red oaks or these species mixed with white oak. Most of the white oak occurs on northern exposures or near the bottom of the slopes and in the stream valleys.

Size and Condition of Trees.—The trees are usually of small size, too small for saw timber. The bulk of the timber from this region goes on the market as ties or cordwood or is used locally for fuel and fencing. Then, too, much of it is defective. As a rule, black jack seldom reaches a size of more than 10 to 12 inches in diameter and when it becomes 3 or 4 inches in diameter it is subject to shake and heart rot. It is rarely used except for fuel. Post oak is usually a rather small tree, reaching in rare cases a diameter in excess of 20 inches. Fire scars, hollow butts and both red and brown heart rot are the commonest defects. On the whole, these two species are the most defective of any found in the Ozark forests. White oak, especially on the small patches of fair soil close to the streams remains sound and becomes a large timber tree. The larger trees on the poor soil are often rotten near the ground. The black or red oaks appear to be comparatively free from defects although some rotten trees are found. It

*Sauer, "The Geography of the Ozark Highland of Missouri," p. 185.

is very probable that one or both of these species should form the main portion of the stand in the future forests in this region.

Fires.—Fires are mainly responsible for the present poor condition of the forest. Farmers have repeatedly burned the woods hoping, by this means to improve the grass and to kill out ticks and brush. As a result, the brush which has been killed back has sent up numerous sprouts from the roots and stumps and now more brush is present than there would have been had the fires never occurred. A small sapling or pole may not be killed by fire as it runs through the woods but the bark on one side will be so scorched that it will crack or fall away, thus allowing heart rot fungi to gain entrance. Scattered throughout the forest are tracts where fire has not done much damage. Here is found a considerable amount of young stuff in the pole stage.

Origin and Reproduction.—The origin of the forest is mostly seedling. Some of the younger trees, poles and saplings are from sprouts put out from the burned stumps of seedlings. Young post and white oak trees up to about 10 to 12 inches on the stump will sprout fairly well and will reproduce a cut over area. The black oaks sprout vigorously up to the time they reach a diameter of 15 inches. The sprouting capacity of fair sized stumps depends somewhat on their height. For example, two 15 inch trees are cut, one with a stump 12 inches high and the other with a 30 inch stump. The 12 inch stump will send up good sprouts but the sprouts from the other, if there be any, will usually die before fall. It is advisable to cut timber in winter if the forest is to be reproduced by sprouts. Where hogs run loose in woods it is almost impossible to secure a new stand of seedling growth and sprouts must be relied on or the tract fenced.

GROWTH STUDIES

Locality and Field Work.—The measurements upon which these growth studies rest were made in the woods northeast of Midco, Missouri, chiefly in Township 27 north and Range 2 west of the Fifth Principal Meridian in Carter County. Here the Mid-Continent Iron Company is engaged in the production of cordwood on a large scale to furnish charcoal for its blast furnace at Midco. The work had the hearty support and cooperation not only of the manager and officers of the company but of the entire personnel at every point where contact was established. Without such co-

operation the results here attained could not have been secured. The field work was done in the summer of 1918. All computations were completed during the year following. The manuscript has been subject to revision particularly in the light of new information of a general nature bearing on tree growth in the Ozarks.

Measurements.—These were made in part on trees cut in the usual course of the company's operations; in part on trees cut by the company in the particular interest of this work. The trees measured were grouped into four species; white oak (Quercus alba L.), post oak (Quercus minor (Marsh.) Sargent), black jack oak (Quercus Marilandica Muenchh.) and black oak (Quercus velutina Lam.) Black oak was extended to include the closely related red oak, Texan oak and Spanish oak.

Numerically these four oaks are represented in this study as follows:

Post Oak	118 trees
Black Oak	114 trees
Black Jack	54 trees
White Oak	49 trees
Total	335 trees

The bole of each of these trees was cut into four-foot lengths and a complete stem analysis was made with ring counts and the usual measurements at each section with the exception of those sections showing defects.

Computation.—The procedure followed in computing volumes and other derived values from the recorded data has been described in the Journal of Forestry,* in connection with a discussion of the mechanical conveniences employed and reference is here made to that article for a detailed statement of the methods used.

RESULTS

Diameter Growth.—Diameter growth was studied by finding the relation between the radial growth during a given decade and the radius at the beginning of that decade. This relation is shown in Figure 1 although, for obvious reasons diameters are here

*Pegg, Ernest C., Mechanical Aids in Stem Analysis, Journal of Forestry, XVII; pp. 682-5: Oct. 1919.

shown, and not radii. A similar study of bark thickness in relation to present diameter inside the bark is the basis for Figure 2. It is obvious that while a single section will serve to locate but a single point on Figure 2 it will locate on Figure 1 as many points as there are full decades in its age.

Tables I to IV show the diameter growth at breast-height for the four species as read from the curves in Figures 1 and 2. The first column is the diameter in inches inside the bark at breast-height, a point 4½ feet above the ground. The second column is the diameter growth (twice the radial growth) of wood laid on during the ten years following the attainment of the diameter shown in the first (and last) columns. The third column is the

TABLE I.—DIAMETER GROWTH AT BREAST-HEIGHT—BLACK OAK.

Inside bark			Thickness of bark	Age on stump	Diameter outside bark
Diameter	Diameter increase in 10 years	Period to increase 1 in. in diameter			
inches	inches	years	inches	years	inches
0	1.20	8	....	3	....
1	1.27	8	.20	11	1.20
2	1.37	7	.38	19	2.38
3	1.47	6	.56	26	3.56
4	1.57	6	.72	32	4.72
5	1.67	6	.84	38	5.84
6	1.72	6	.94	44	6.94
7	1.74	6	1.00	50	8.00
8	1.73	6	1.06	56	9.06
9	1.72	6	1.10	62	10.10
10	1.68	6	1.14	68	11.14
11	1.63	6	1.18	74	12.18
12	1.57	6	1.24	80	13.24
13	1.53	7	1.31	86	14.31
14	1.47	7	1.39	93	15.39
15	1.44	7	1.50	100	16.50
16	1.41	7	1.63	107	17.63
17	1.38	7	1.77	114	18.77
18	1.35	7	1.92	121	19.92
19	....	...	2.07	128	21.07

number of years required to make an increase of 1 inch in diameter of wood (not including bark growth). It is computed from the second column. The fourth column shows the average double thickness of bark for each inch class of wood diameter. The initial value in the fifth column is derived from field data but all subsequent values are derived in turn by adding to the value in column five the value in column three. The last column is the diameter outside the bark and is the sum of the first and fourth columns. It is the value obtained in calipering standing trees at breast-height (D. B. H.). When plotted the data in columns five and six give the curves shown in Figure 3.

Height-Growth.—The relation between diameter at breast-height outside the bark and the total height of the tree as computed from the field data is shown in Figure 4. It will be noted on this figure that the course for white oak, post oak and black jack oak coincide below 15 feet and the curves for post oak and black jack coincide below 40 feet.

Volume Growth.—The volume of a tree is either its total gross volume or that portion of its gross volume which is used—

TABLE II.—DIAMETER GROWTH AT BREAST-HEIGHT—BLACK JACK OAK.

Inside bark			Thickness of bark	Age on stump	Diameter outside bark
Diameter	Diameter increase in 10 years	Period to increase 1 in. in diameter			
inches	inches	years	inches	years	inches
0	1.16	9	....	4	....
1	1.15	9	.23	13	1.23
2	1.13	9	.47	22	2.47
3	1.13	9	.63	31	3.63
4	1.13	9	.80	40	4.80
5	1.15	9	.96	49	5.96
6	1.17	8	1.10	58	7.10
7	1.18	8	1.24	66	8.24
8	1.19	8	1.38	74	9.38
9	1.20	8	1.54	82	10.54
10	1.22	8	1.73	90	11.75
11	....	...	1.90	98	12.90

the net volume. Since gross volume possesses a great scientific but small practical value it is usually expressed in solid measure as in cubic feet. That portion of the total volume which finds commercial use—the net volume—is ordinarily expressed in the commercial unit of measurement; in this case the cord. To facilitate comparison with the total volume the used volume is also expressed in cubic feet. The relationships of these volumes to the diameter at breast-height are shown in Figures 5, 6 and 7.

Tables V to VIII were read from the curves of Figures 3, 4, 5, 6, and 7. The first column shows the diameter outside the bark at breast-height; the following five columns show the corresponding values read from the five curves. The last column shows the distribution of the trees measured among the different diameter-

TABLE III.—DIAMETER GROWTH AT BREAST-HEIGHT—WHITE OAK.

Inside bark			Thickness of bark	Age on stump	Diameter outside bark
Diameter	Diameter increase in 10 years	Period to increase 1 in. in diameter			
inches	inches	years	inches	years	inches
0	1.05	9	....	5	....
1	1.05	9	.15	14	1.15
2	1.05	9	.30	23	2.30
3	1.05	10	.43	32	3.43
4	1.03	10	.55	42	4.55
5	1.02	10	.64	52	5.64
6	1.00	10	.72	62	6.72
7	1.00	10	.79	72	7.79
8	1.00	10	.87	82	8.87
9	1.03	10	.97	92	9.97
10	1.07	9	1.08	102	11.08
11	1.12	9	1.16	111	12.16
12	1.16	9	1.23	120	13.23
13	1.20	8	1.28	129	14.28
14	1.22	8	1.36	137	15.36
15	1.24	8	1.45	145	16.45
16	1.25	8	1.55	153	17.55
17	1.25	8	1.67	161	18.67
18	....	...	1.79	169	19.79

The diameter growth of white oak in Carter County falls uniformly about one-quarter inch below the diameter growth for seedling white oak in Kentucky and Tennessee until an age of 130 years is reached. At 140 years the two curves cross and growth in the Ozarks thereafter rises sharply above that east of the river. This may be a result however of a difference of procedure in constructing the two curves.

The diameter growth of seedling chestnut oak in Kentucky and Tennessee is almost identical with that of white oak in Missouri until an age of 100 years is reached. Beyond that the chestnut oak falls behind very distinctly.

Except during the first three decades the diameter growth of black oak in Missouri is more rapid than that of black oak east of

TABLE VI.—RELATION OF AGE, HEIGHT AND VOLUME TO DIAMETER AT BREAST-HEIGHT—BLACK JACK OAK.

D. B. H. outside bark	Age on stump	Total height	Volume			No. of
			Total	Used		
inches	years	feet	cu. ft.	cu. ft.	cords	trees
1	11	9.5	.....	.....	.....	.....
2	19	15.0	.4	.....	.....	.....
3	26	20.5	.5	.4	.006	.....
4	34	26.5	1.0	.8	.014	.....
5	41	31.5	1.9	1.7	.024	12
6	49	36.0	3.4	3.1	.042	15
7	57	39.5	5.2	4.7	.061	7
8	65	42.5	7.2	6.5	.089	5
9	72	44.5	9.4	8.5	.115	10
10	78	46.5	11.5	10.6	.146	1
11	85	48.0	14.2	13.2	.186	1
12	92	49.5	17.5	16.0	.235	1
13	.....	51.0	21.4	19.3	.300	1
14	.....	52.5	25.5	23.1	.373	1
15	.....	53.5	29.8	26.8	.452	.....
16	.....	.....	34.4	30.6	.....	.....
						54

the river, the two curves crossing at 45 years. This may be due to the failure in this work to separate red oak from black oak. There is no data for seedling red oak in Kentucky.

A comparison of the form of these Ozark oaks with those from Kentucky and Tennessee on the basis of the measurements just made shows that the Ozark oaks have a considerably greater taper. Ozark black oaks of a given diameter are about 3 feet

TABLE VII.—RELATION OF AGE, HEIGHT AND VOLUME TO DIAMETER AT BREAST-HEIGHT—WHITE OAK.

D. B. H. outside bark	Age on stump	Total height	Volume			No. of
			Total	Used		
inches	years	feet	cu. ft.	cu. ft.	cords	trees
1	12	9.5	.....	.....	.....	.....
2	20	15.0	.6	.....	.....	.....
3	28	20.0	1.0	.8	.006	.....
4	36	25.2	1.5	1.3	.014	1
5	45	30.5	2.5	2.2	.024	3
6	54	35.5	3.7	3.4	.042	5
7	64	40.0	5.4	5.0	.061	5
8	73	44.2	7.4	7.0	.089	3
9	82	48.0	10.0	9.2	.126	3
10	91	51.5	13.0	11.8	.172	3
11	100	54.5	16.3	14.7	.227	2
12	109	57.5	20.4	18.0	.295	3
13	117	60.0	24.7	21.7	.367	5
14	126	62.0	29.3	26.0	.454	1
15	134	63.5	34.5	30.6	.550	2
16	141	65.2	39.8	35.6	.648	3
17	148	66.5	45.4	41.0	.764	7
18	155	67.5	51.5	46.8	.885	.....
19	162	68.5	58.3	53.2	1.015	2
20	170	69.5	65.5	60.0	1.148	1
21	.....	70.5	72.7	67.5	1.280	.....
22	.....	71.5	85.2	76.0	1.430	.....
23	.....	72.5	.....	.....	.....	.....
						49

shorter until a diameter of fifteen inches is reached; beyond this point the disparity increases until at twenty-two inches Missouri trees have attained a height of but 74 feet as against 85 feet for trees across the river.

The disparity is even greater in the case of the white oak. A difference in height of 5 feet (25-30) at 4 inches increases to a difference of 18 feet (70-88) at 20 inches D. B. H.

TABLE VIII.—RELATION OF AGE, HEIGHT AND VOLUME TO DIAMETER AT BREAST-HEIGHT—POST OAK.

D. B. H. outside bark	Age on stump	Total height	Volume			No. of
			Total	Used		
inches	years	feet	cu. ft.	cu. ft.	cords	trees
1	13	9.5	.....	.....	.....	.....
2	22	15.0	.5	.....	.....	.....
3	31	20.2	.8	0.7	.006	.....
4	42	26.5	1.4	1.2	.014	4
5	53	31.5	2.3	2.1	.024	11
6	65	36.0	3.5	3.3	.040	16
7	76	39.7	5.4	4.8	.058	10
8	88	42.7	7.5	6.5	.088	15
9	100	45.0	9.5	8.5	.123	13
10	112	47.0	12.0	10.7	.165	11
11	124	49.0	15.0	13.3	.214	8
12	134	50.5	18.2	16.2	.272	6
13	145	52.0	22.0	19.8	.327	7
14	157	53.5	26.2	23.9	.388	5
15	172	54.7	30.7	28.0	.460	6
16	193	55.7	35.8	32.6	.537	3
17	.....	57.0	41.5	38.0	.622	1
18	.....	58.0	47.7	44.0	.708	2
19	.....	58.7	54.5	50.2	.800	.....
20	.....	59.5	61.6	57.0	.897	.....
21	.....	60.2	69.2	64.3	.996	.....
22	.....	61.0	76.8	71.7	.....	.....
23	.....	61.7	.....	.....	.....	.....
						118

Lack of data prevents the drawing of similar comparisons for black jack oak and post oak.

YIELDS OF SAMPLE ACRES

As a check four sample acres were laid off, felled, cut into 4-foot lengths, corded up and measured. All four of the plots were located on dry Clarksville stony loam where occasional fires have destroyed almost all the leaves and other litter. Many of the trees were fire-scarred and more or less rotten at the base. The post and white oak seemed to be particularly subject to rot after fire.

Plot I was a very open stand on a northern exposure. It lay just over the break on a rather steep slope. The ground was fairly well covered with grass and weeds but there was very little litter, mineral soil being exposed over almost the entire tract. Loose rock fragments were abundant. A few saplings grew in the

TABLE IX.—TALLY OF TREES ON PLOT I.

D. B. H. Inches	Number of Trees.		
	Black Oak	White Oak	Post Oak
5	1	.....	.....
6	1	1	2
7	1	1	1
8	4	2	1
9	1	1	1
10	2	1	1
11	2	1	1
12	2	.....	.....
13	1	.....	.....
14	2	.....	1
15	1	.....	2
16	2	2	.....
17	.....	1	1
18	.....	.....	1
19	1	1	.....
Total.....	21	11	12

Grand Total.....44 Trees Yield.....14.75 Cords

more open spots but smaller trees were absent. The number and size of the trees are shown in Table IX.

Plot II contained 142 trees, most of which were of small size. The slope was gentle, being on one side of a rather broad ridge and was exposed to the south. The forest cover was too dense to permit the growth of young trees or more than a scattering stand of grass. The tally of trees is as shown in Table X.

Plot III was on a very steep, rocky slope with a northeastern exposure. The stand was of medium density with very little young timber or undergrowth. Herbaceous growth was also very light. The soil was very rocky and exposed for the most part, covered in spots with a loose layer of leaves. Table XI shows the number and size of trees.

Plot IV was situated on a moderate slope with a northern exposure. It was a fairly dense stand with no reproduction and no

TABLE X.—TALLY OF TREES ON PLOT II.

D. B. H. inches	Number of Trees.			
	Black Oak	Black Jack	White Oak	Post Oak
4	.....	.....	1	1
5	3	11	1	5
6	3	12	2	11
7	3	7	.....	2
8	2	5	1	8
9	2	6	.....	10
10	9	.....	.....	3
11	4	1	.....	5
12	4	.....	.....	3
13	2	.....	1	5
14	1	1	.....	1
15	.....	.....	.....	.....
16	1	.....	1	3
17	.....	.....	.....	.....
18	.....	.....	.....	1
Total.....	34	43	7	58

Grand Total.....142 Trees Yield.....20.63 Cords.

saplings. In a few places there was a fair growth of weeds and grass but on most of the area the bare rocky soil was exposed. The number and size of trees is given in Table XII.

At the bottom of each table is given the yield of the sample acre in cords. These are the figures obtained by stacking the cut wood and measuring the dimension of the pile. It is instructive to compare this observed volume with the volume as computed from the tally of the trees on each acre by the use of the volume tables.

This table furnished us with a criterion of the accuracy with which the volume tables already computed can be applied. The average error on these four plots is 3 per cent and this is consid-

TABLE XI.—TALLY OF TREES ON PLOT III.

D. B. H. Inches	Number of Trees.			
	Black Oak	Black Jack	White Oak	Post Oak
4	.....	.....	.....	1
5	2	1	1	4
6	1	3	.....	2
7	2	.....	.....	4
8	5	.....	.....	4
9	3	4	.....	2
10	.....	1	1	5
11	6	.....	.....	2
12	1	1	.....	3
13	2	1	.....	1
14	1	.....	.....	3
15	1	.....	.....	4
16	1	.....	.....	.....
17	3	.....	1	.....
18	1	.....	.....	.....
19	.....	.....	.....	.....
20	.....	1	.....	.....
21	1	.....	.....	.....
Total.....	30	12	3	35

Grand Total.....80 Trees. Yield.....20.87 Cords.

TABLE XII.—TALLY OF TREES ON PLOT IV.

D. B. H. Inches	Number of Trees.		
	Black Oak	White Oak	Post Oak
4	1	.....	2
5	.....	1	2
6	.....	4	1
7	3	2	3
8	3	.....	2
9	2	2	.....
10	1	1	2
11	4	2	.....
12	1	2	.....
13	2	4	1
14	5	1	.....
15	.....	2	.....
16	1	.....	.....
17	2	5	.....
18	.....	.....	.....
19	1	1	.....
20	1	1	.....
21	1	.....	.....
Total.....	28	28	13

Grand Total.....69 Trees. Yield.....22.62 Cords.

TABLE XIII.—COMPARISON OF OBSERVED AND COMPUTED YIELDS.

Plot	Trees Number	Observed Volume Cords	Computed Volumes Cords	Error Percent
I	44	14.75	13.74	—6.8
II	142	20.63	20.41	—1.1
III	80	20.87	19.59	—6.1
IV	69	22.62	22.98	+1.6

ered a satisfactory degree of accuracy in view of the loose (and accordingly variable) practice followed in stacking cordwood. Moreover the tables err in the direction of understatement which is the less objectionable direction.

ACKNOWLEDGMENT

The plan of the investigation here reported is the joint work of the authors. The field work was carried out at Midco, Missouri in the summer of 1918 by Professor Pegg and Mr. F. R. Bruto. All computations were performed by Professor Pegg the following autumn at Columbia. Most of the figures and tables are published as prepared by him. His assistance has not been available in the final preparation of the letterpress because of his resignation from the University of Missouri and it has not been possible to submit it to him for his criticism.

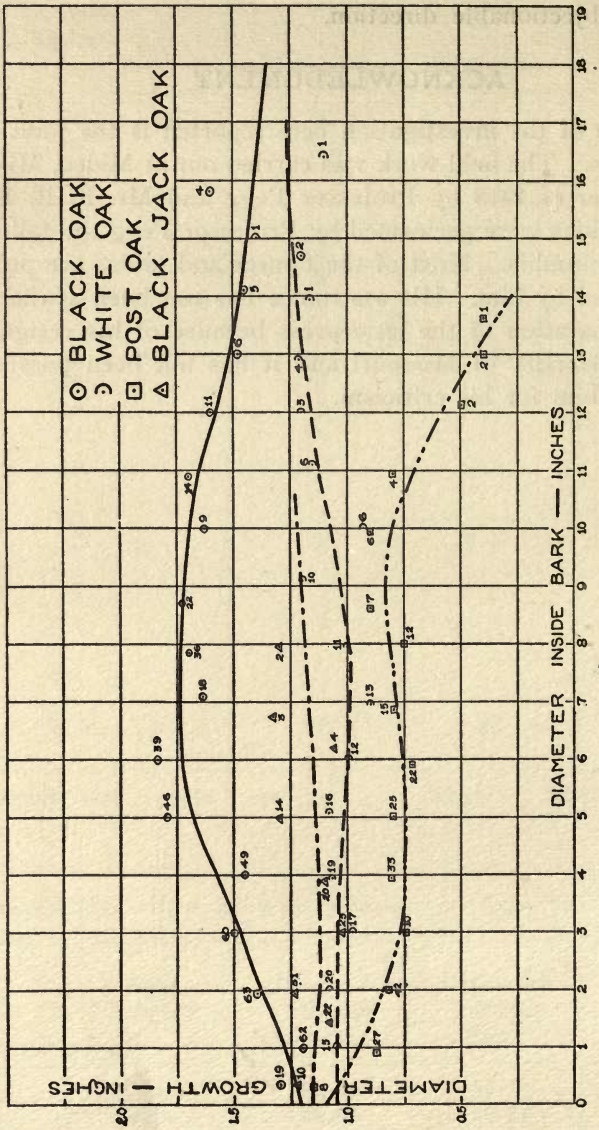


Figure 1.—Relation between diameter growth of wood per decade at breast-height and initial diameter inside the bark. The points shown on this and suceeding curves are averages by inch-classes. The numbers show how many readings are averaged in each point.

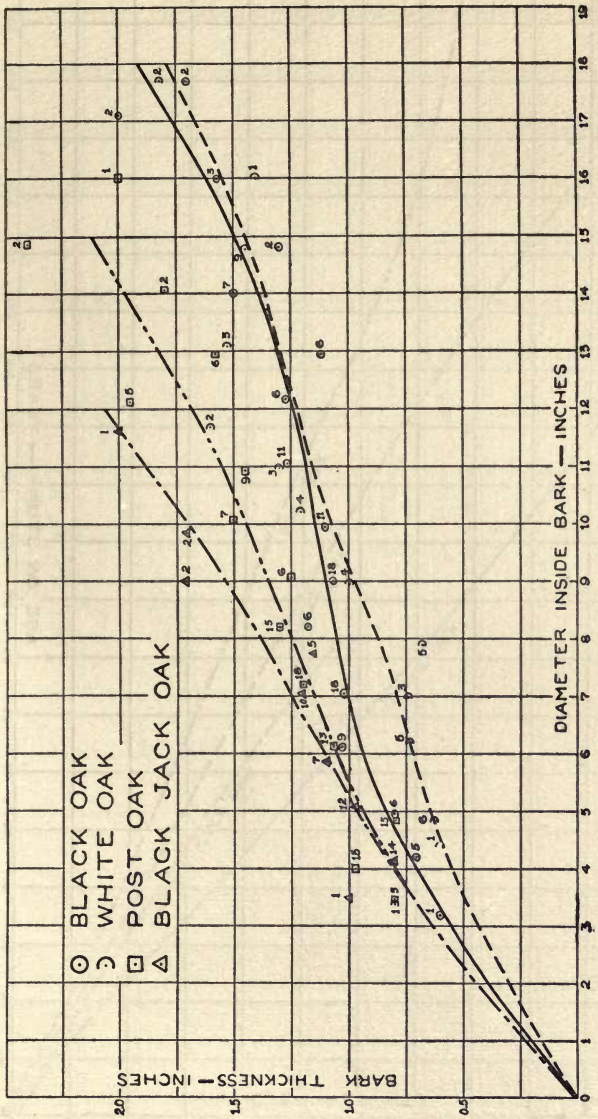


Figure 2.—Relation between bark thickness and diameter inside the bark at breast-height.

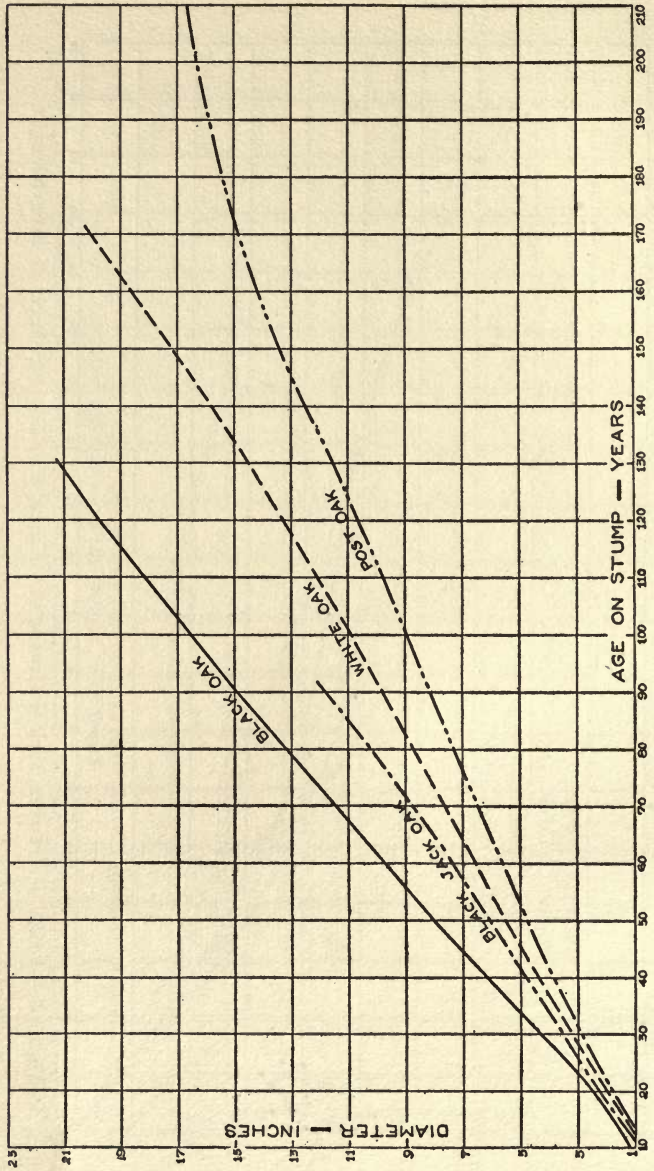


Figure 3.—Relation between age on the stump and diameter outside the bark at breast-height.

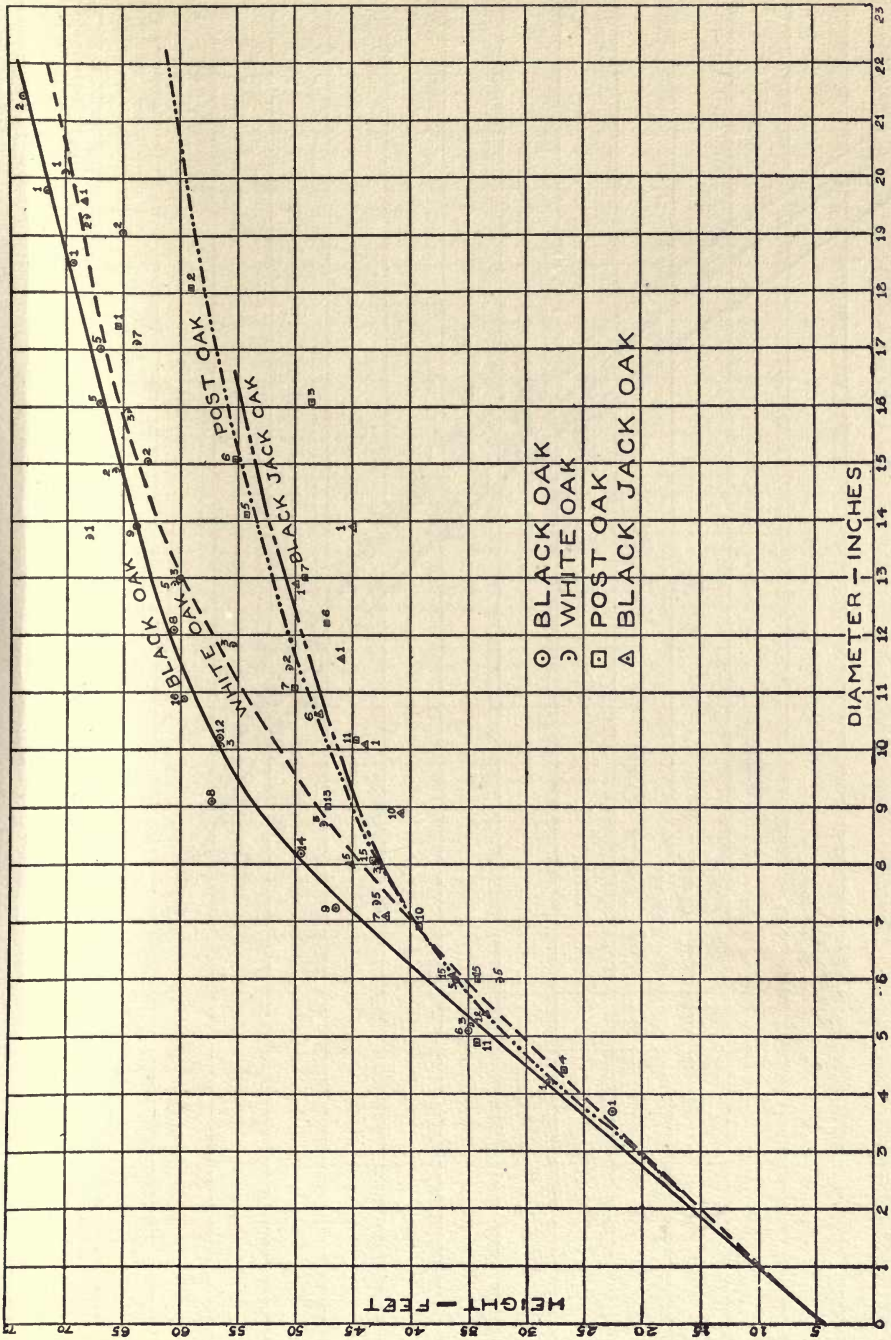


Figure 4.—Relation between total height of tree and diameter outside the bark at breast-height.

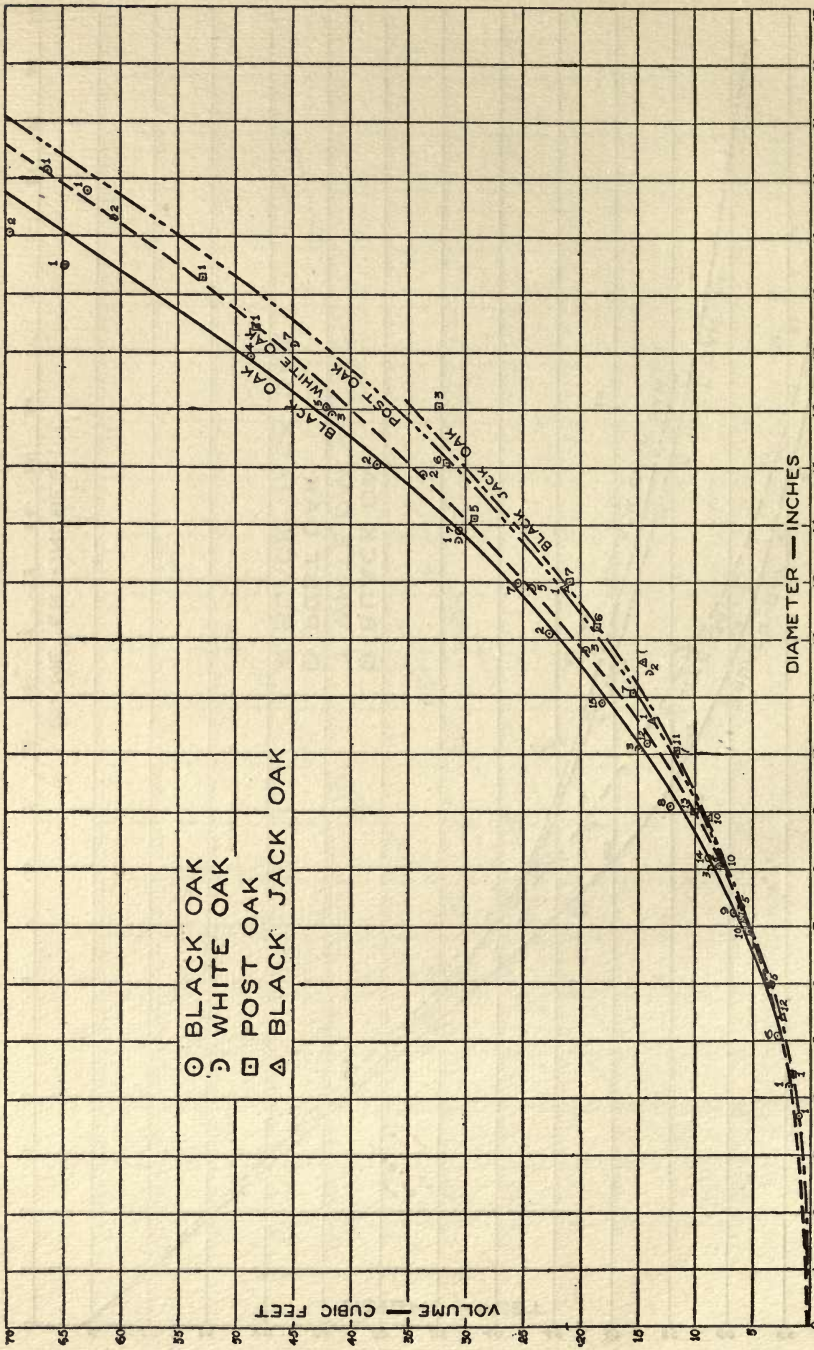


Figure 5.—Relation between total volume of tree and diameter outside the bark at breast-height.

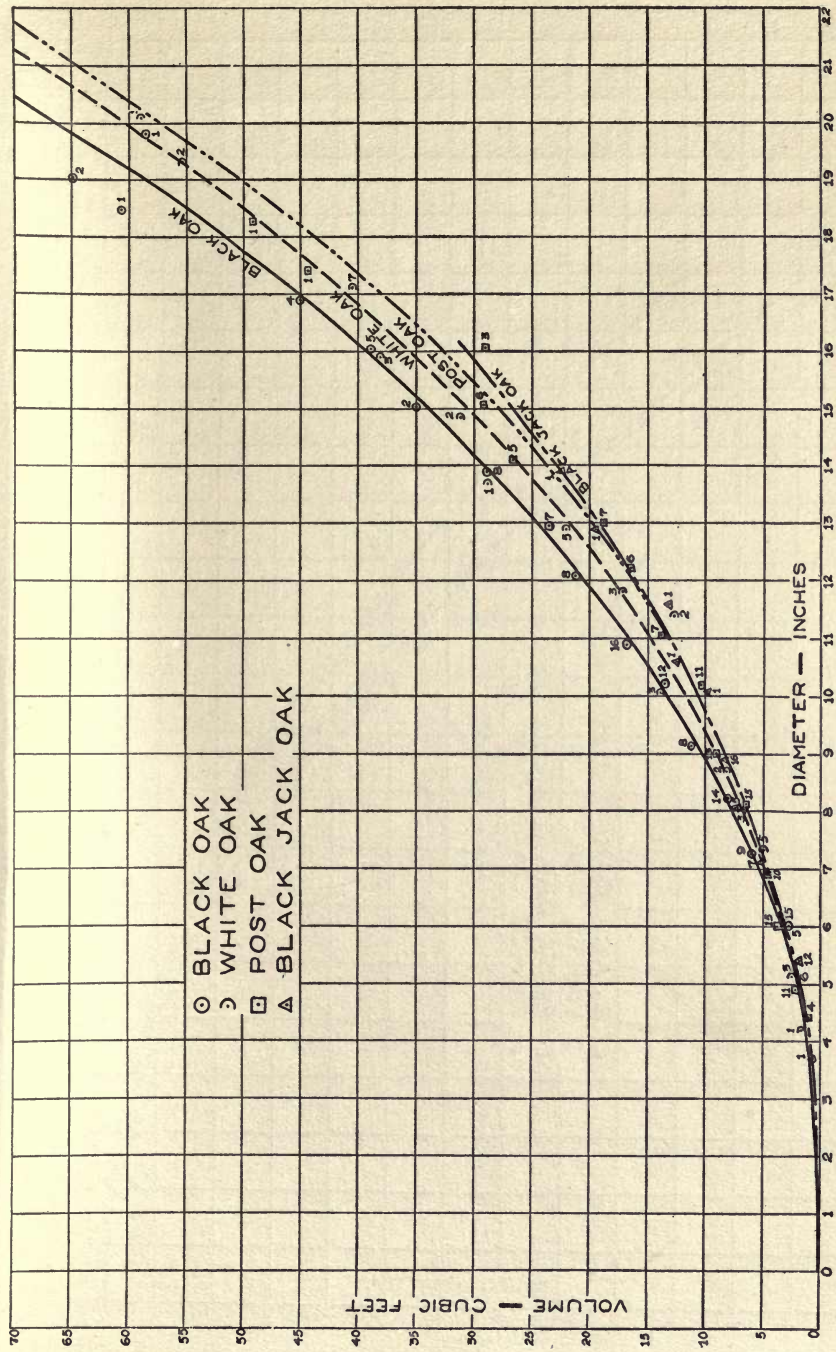


Figure 6.—Relation between used volume of tree and diameter outside the bark at breast-height. Volumes in cubic feet.

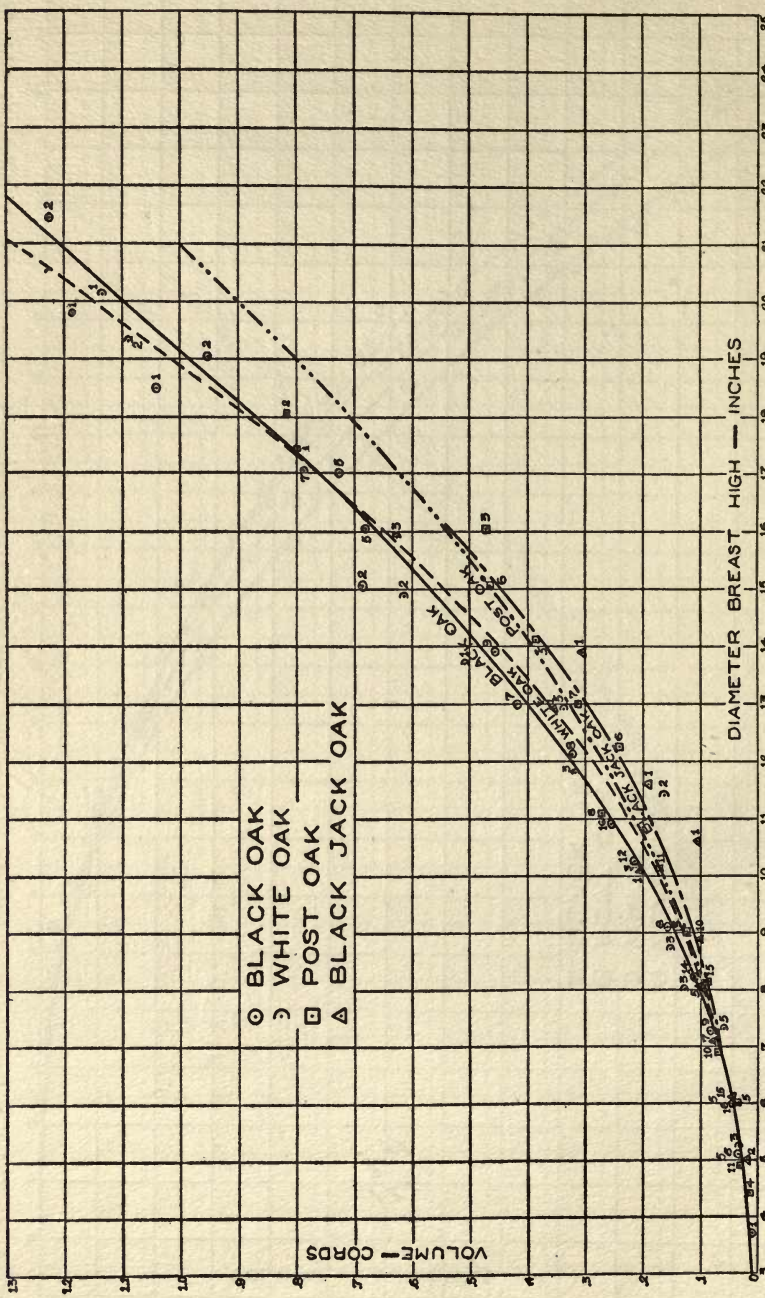


Figure 7.—Relation between used volume of tree and diameter outside the bark at breast-height. Volumes in cords.

Dunlap, Frederick.
Growth of oak in the
Ozarks.